AMD
Thermal, Mechanical, and Chassis Cooling Design Guide

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Revision History

Date	Rev	Description
November 2002	H	Updated values in Tables 1, 2, 3, 4, 5, and 6, and updated dimensions throughout. Added Fan Considerations section. Updated PS photos and updated airflow diagram.
March 2002	G	Updated Table 1 and Table 3 for total die size, A_{core}, and $p_{thermal}$ max values.
January 2002	F	Updated Figure 5, "Motherboard Keepout Area for a Socket A AMD Athlon™ Processor Heatsink," on page 11, removing the four mounting holes.
November 2001	E	Added Bergquist, Honeywell, Power Devices, and ShinEtsu to the list of Vendors in Table 7, "Suggested Thermal Interface Materials," on page 6.
March 2001	D	Corrected Athlon™ and Duron™ processor die sizes in tables 1 and 2 on page 4.
February 2001	C	Corrected Max. Length for heatsink from blank to 60mm, and corrected Min. Length for heatsink from 60mm to blank in Table 4 and in Table 6.
October 2000	B	■ Added mention of AMD Duron processor in the text and added the following tables and figures with AMD Duron information: Table 3 on page 4, Table 6 on page 6, and Figure 6 on page 12. ■ Revised "Suggested Interface Materials" on page 6, and Table 7 on page 6. ■ Added Section, "Thermocouple Installation for Temperature Testing" on page 13, and added Figure 7 through Figure 10.
May 2000	A	Initial release based on AMD Athlon Processor Family Thermal Cooling Requirements Version 2.1.

AMD Thermal, Mechanical, and Chassis Cooling Design Guide

This document specifies performance requirements for the design of thermal, mechanical, and chassis cooling solutions for the AMD Athlon™ and AMD Duron™ processors. In addition to providing design targets, drawings are provided from an AMD-designed solution meeting the requirements of the AMD Athlon and AMD Duron processors.

Summary of Requirements

To allow the optimal reliability for AMD Athlon and AMD Duron processor-based systems, the thermal design solution should dissipate heat from a theoretical processor running at a given maximum thermal power. The following sections specify recommended values for these optimal thermal parameters. By setting a high-power target, the engineer may avoid redesigning a point solution heatsink/fan sink, thus increasing the life of the particular thermal solution.

PGA Socket A-Based Processor Thermal Requirements

The first step to achieving proper thermal performance is to dissipate the heat generated by the processor. This, normally, is accomplished by use of a heatsink of some design. The following section includes the specifications required to have a proper heatsink design for Socket A processors.

Socket Description

Socket A is a PGA socket designed for socketed AMD Athlon™ and AMD Duron™ processors. Figure 1 shows the socket layout.

Note: *The figure socket is labeled SOCKET 462, which is synonymous with the Socket A.*

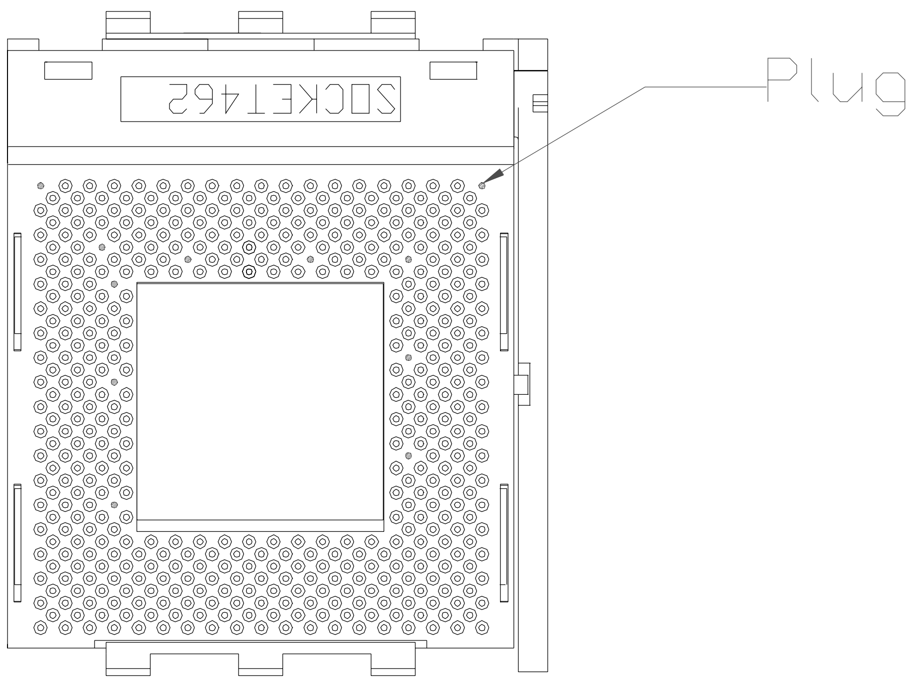


Figure 1. Socket A

Socket A is very similar in form factor to previous sockets, such as Socket 7. Socket A incorporates additional pins in the inner portion of the socket. Thus, a thermal solution for Socket A can leverage preexisting design efforts.

Figure 2 on page 3 details the physical dimensions of Socket A.

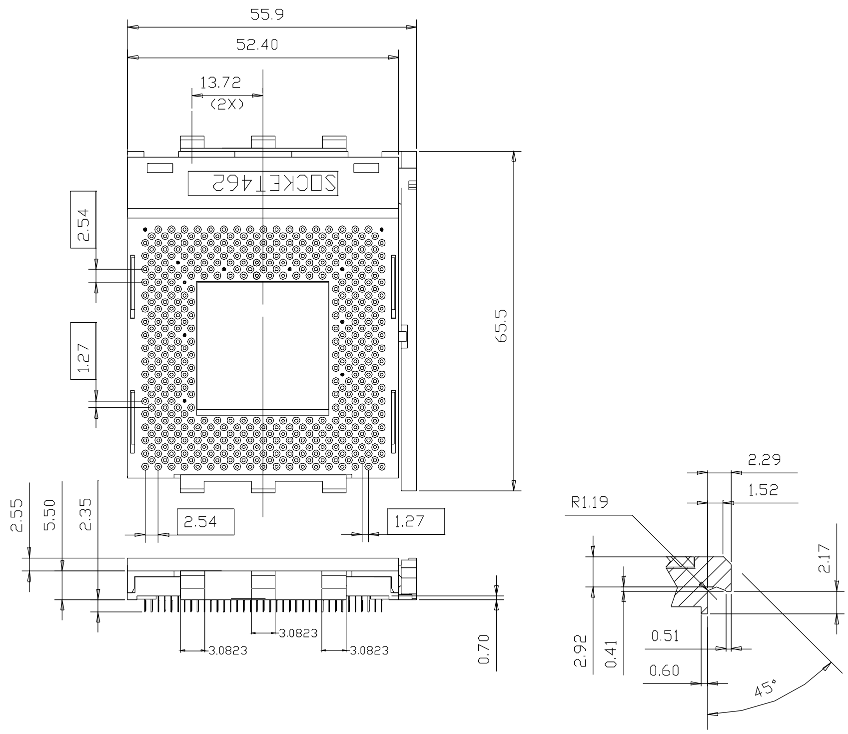


Figure 2. Dimensions of Socket A

Socket A-Based Processor Specifications

Table 1, Table 2 on page 4, and Table 3 on page 4 list the thermal specifications of the socketed AMD Athlon and AMD Duron processors.

Table 1. Socketed Processor Specifications for the AMD Athlon™ Processor Model 6

Symbol	Description	Max Value	Notes
T_{die}	Maximum die temperature	90ºC	
Total die size	Die size	129.26 mm^2	Includes L2 cache
A_{core}	Core area	105.72 mm^2	Die size not including L2 cache
Form factor	Heatsink form factor	PGA	PGA Socket A form factor
$P_{thermal}$	Max processor thermal power	72.0 W	Required supported power

Table 2. Socketed Processor Specifications for the AMD Athlon™ Processor Model 8

Symbol	Description	Max Value	Notes
T_{die}	Maximum die temperature	90°C	For Model 2100+ and below
		85°C	For Model 2200+ and above
Total die size	Die size	80.89 mm^2	Includes L2 cache. For CPUID = 680 only.
		84.66 mm^2	Includes L2 cache. For CPUID = 681 only.
		86.97 mm^2	Includes L2 cache. For CPUID = 682 only.
A_{core}	Core area	67.35 mm^2	Die size not including L2 cache. For CPUID = 680 only.
		71.12 mm^2	Die size not including L2 cache. For CPUID = 681 only.
		73.43 mm^2	Die size not including L2 cache. For CPUID = 682 only.
Form factor	Heatsink form factor	PGA	PGA Socket A form factor
$P_{thermal}$	Max processor thermal power	68.4 W	Required supported power

Table 3. Socketed Processor Specifications for the AMD Duron™ Processor Model 7

Symbol	Description	Max Value	Notes
T_{die}	Maximum die temperature	90°C	
Total die size	Die size	105.68 mm^2	Includes L2 cache
A_{core}	Core area	99.61 mm^2	Die size not including L2 cache
Form factor	Heatsink form factor	PGA	PGA Socket A form factor
$P_{thermal}$	Max processor thermal power	60.0 W	Required supported power

General Socketed Design Targets

To maintain the die temperature of the processor below the maximum T_{die} value, certain heatsink design points must be considered. Table 4 details additional specifications that must be met for the AMD Athlon processor model 6 to reliably operate.

Table 4. General Socketed Thermal Solution Design Target for the AMD Athlon™ Processor Model 6

Symbol	Description	Min	Max	Notes

Table 4. General Socketed Thermal Solution Design Target for the AMD Athlon™ Processor Model 6

L	Length of heatsink		63 mm	Measurements are for the entire assembly, including attached fan.
W	Width of heatsink	60 mm	80 mm	
H	Height of heatsink		64 mm	
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
m_{HS}	Mass of heatsink		300 g	
F_{clip}	Clip force	12 lb	24 lb	Typical F: 14 lb≤ F ≤18 lb Nominal F = 16 lb
T_A	Inside the box local ambient temperature		42ºC	

Table 5 details additional specifications that must be met for the AMD Athlon processor model 8 to reliably operate.

Table 5. General Socketed Thermal Solution Design Target for the AMD Athlon™ Processor Model 8

Symbol	Description	Min	Max	Notes
L	Length of heatsink		63 mm	Measurements are for the entire assembly, including attached fan.
W	Width of heatsink	60 mm	80 mm	
H	Height of heatsink		64 mm	
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
m_{HS}	Mass of heatsink		300 g	
F_{clip}	Clip force	12 lb	24 lb*	Typical F: 18 lb ≤ F ≤ 22 lb Nominal F = 20 lb
T_A	Inside the box local ambient temperature		42ºC	

Notes:
** Clip force as high as 30 lb is acceptable if using a 6-tab clip.*

Table 6 shows the thermal solution design target for the AMD Duron processor.

Table 6. General Socketed Thermal Solution Design Target for the AMD Duron™ Processor

Symbol	Description	Min	Max	Notes
L	Length of heatsink		63 mm	Measurements are for the entire assembly, including attached fan.
W	Width of heatsink	60 mm	80 mm	
H	Height of heatsink		64 mm	
CFM	Fan airflow	16 cfm		Minimum 16 cfm airflow
m_{HS}	Mass of heatsink		300 g	
F_{clip}	Clip force	12 lb	24 lb	Typical F: 14 lb ≤ F ≤ 18 lb Nominal F = 16 lb
T_A	Inside the box local ambient temperature		50° C	

Suggested Interface Materials

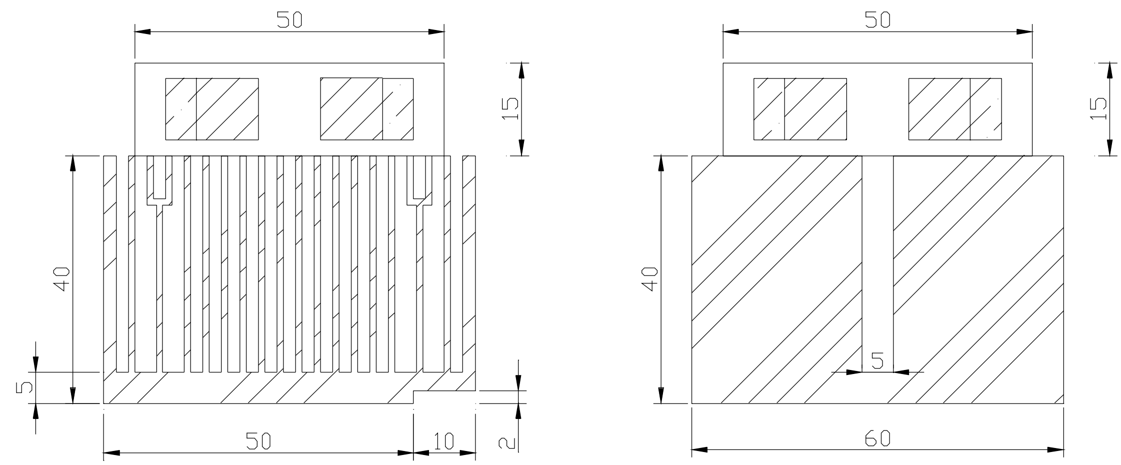
AMD evaluates thermal interface materials for socketed designs. A list of suggested materials tested by AMD is provided in Table 7. If the heatsink needs to be removed, the phase change material must be replaced on the heatsink before re-installing the heatsink. Use a plastic scraper to gently remove the old phase change material from the heatsink.

Table 7. Suggested Thermal Interface Materials

Vendor	Interface Material	Material Type
Bergquist	HF225UT	Phase Change
Chomerics	T725	Phase Change
Honeywell	PCM45	Phase Change
Power Devices	Powerfilm	Phase Change
ShinEtsu	PCS-TC-11T-13	Phase Change
Thermagon	T-pcm905C	Phase Change

Sample Socket A Heatsink Drawings

Figure 3 provides a reference drawing of a heatsink AMD has designed to work with Socket A processors.



Measurements are in millimeters

Figure 3. Sample Drawing of Socket A Heatsink

Socket A Heatsink Design Considerations

Heatsink design considerations include the characteristics of the heatsink itself, the clip used to hold the heatsink to the processor, the thermal interface material between the heatsink and the processor, and the length of the fan wire for active heatsinks.

Heatsink Considerations

The important design parameters of the socket A heatsink include the dimensions of the flat base, the maximum base footprint, and the clearance over the socket cam.

Flat base to contact support pads. The PGA processor is housed in a 50 x 50 mm ceramic package. The heatsink makes direct contact with the flip-chip die. While the die dimensions are considerably less than the 50 mm x 50 mm package footprint, the heatsink base must maintain a minimum flat surface of 46 mm x 46 mm centered on the package and 48 mm x 48 mm at a maximum. This positioning is required for the heatsink to make contact with compliant load support pads. The pads protect the die from mechanical damage during heatsink

installation, as well from shock and vibration. Figure 4 details the ceramic package and compliant load support pads.

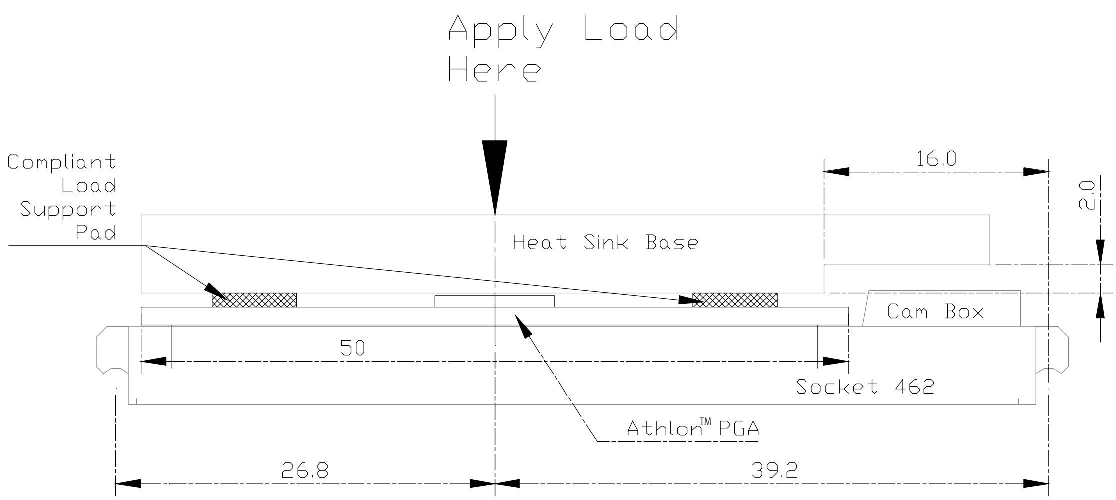


Figure 4. Heatsink and Load Pads

Maximum base footprint of 63 mm x 80 mm. The maximum base footprint for socket heatsinks is 63 mm x 80 mm (as detailed in Figure 3 on page 7). Not all processor speeds require the full 63 mm x 80 mm footprint. Heatsinks with approximately 60 mm x 60 mm footprints have proven to be adequate for low to moderate clock frequencies.

Clearance in heatsink base for socket cam box. The heatsink base must have enough clearance so that it does not contact the cam box on the socket. The clearance zone is defined in the example shown in the Figure 3 on page 7 and Figure 4.

Clip Considerations

The important design parameters of the socket A heatsink clip include the load applied to the heatsink, where the load is applied, how the clip ensures the location of the heatsink in relation to the processor package and socket, and ease of installation.

Load target of 16 lb with range of 12–24 lb. The clip load is greater than that allowed for previous processors with similar mechanical form factors. Table 4 on page 4 details the clip force requirements.

Load applied directly over center of die (asymmetric design). To ensure adequate thermal interface performance between the flip-chip die and the heatsink, the clip must apply its load to the heatsink along a single contact axis. The load should be applied 26.8 mm from the front (non-cam side) socket tab load point (see Figure 4 on page 8). The acceptable tolerance for off-center clip load is ± 1.5 mm.

Feature to lock relative position of heatsink, clip, and socket. A locking feature is needed to avoid incorrect placement of the heatsink on the package. Such a lock can be constructed with small tabs that project from the sides of the clip and fit into a heatsink channel.

Installation features designed to minimize operator fatigue. The clip load requirements of the socketed processor are significantly higher than past models. Emphasis should be focused on providing a clip design that is easily installed. While clips that do not require tools for installation offer some advantages, designs that accept a flat-head screwdriver (or nutdriver) near the clip hook have certain advantages. Such advantages include the ability to pry the clip hook over the socket tab during installation and the ability to install the clips onto the tabs in areas that are tightly confined by motherboard components surrounding the socket.

Thermal Interface Considerations

Many customers have indicated a preference for pre-applied thermal interface materials. A heatsink vendor that chooses to offer pre-applied interface materials should apply a 25 x 25 mm pad centered 25 mm from the front edge of the heatsink.

Fan Considerations

An active heatsink design incorporates a fan mounted to the heatsink. To ensure that the heatsink fan wire can reach power connectors on all Socket 462-based boards, the fan wire length should be at least 8 inches.

Socketed Motherboard Restrictions

The motherboard design and layout must meet certain restrictions to ensure that the socketed thermal solution does not impede the performance of components on the motherboard. To maintain adequate airflow around the microprocessor, certain areas on the motherboard must be free of projecting components. Figure 5 on page 11 shows these keepout areas on the motherboard for an AMD Athlon processor, and Figure 6 on page 12 shows the motherboard keepout area for an AMD Duron processor.

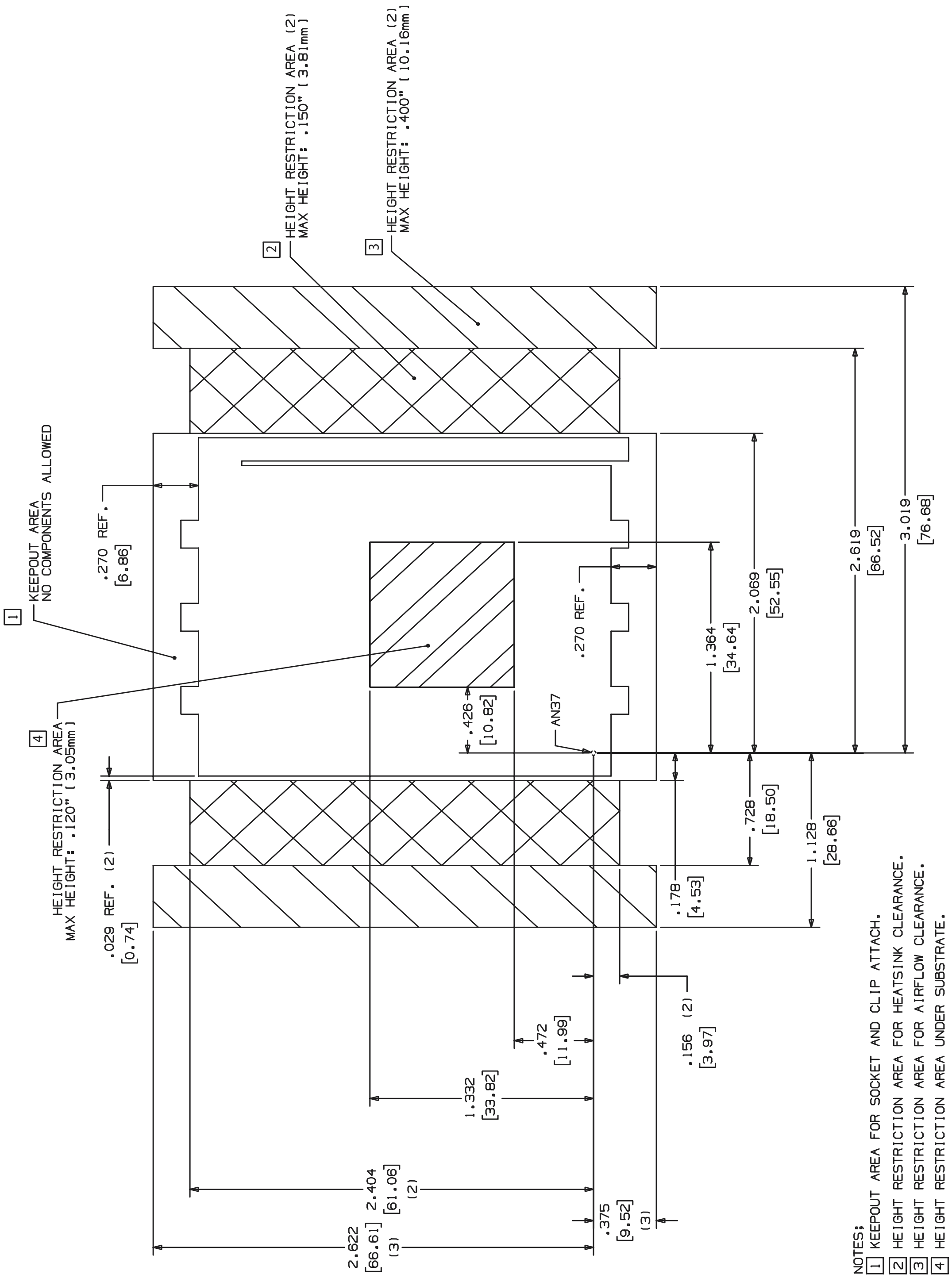


Figure 5. Motherboard Keepout Area for a Socket A AMD Athlon™ Processor Heatsink

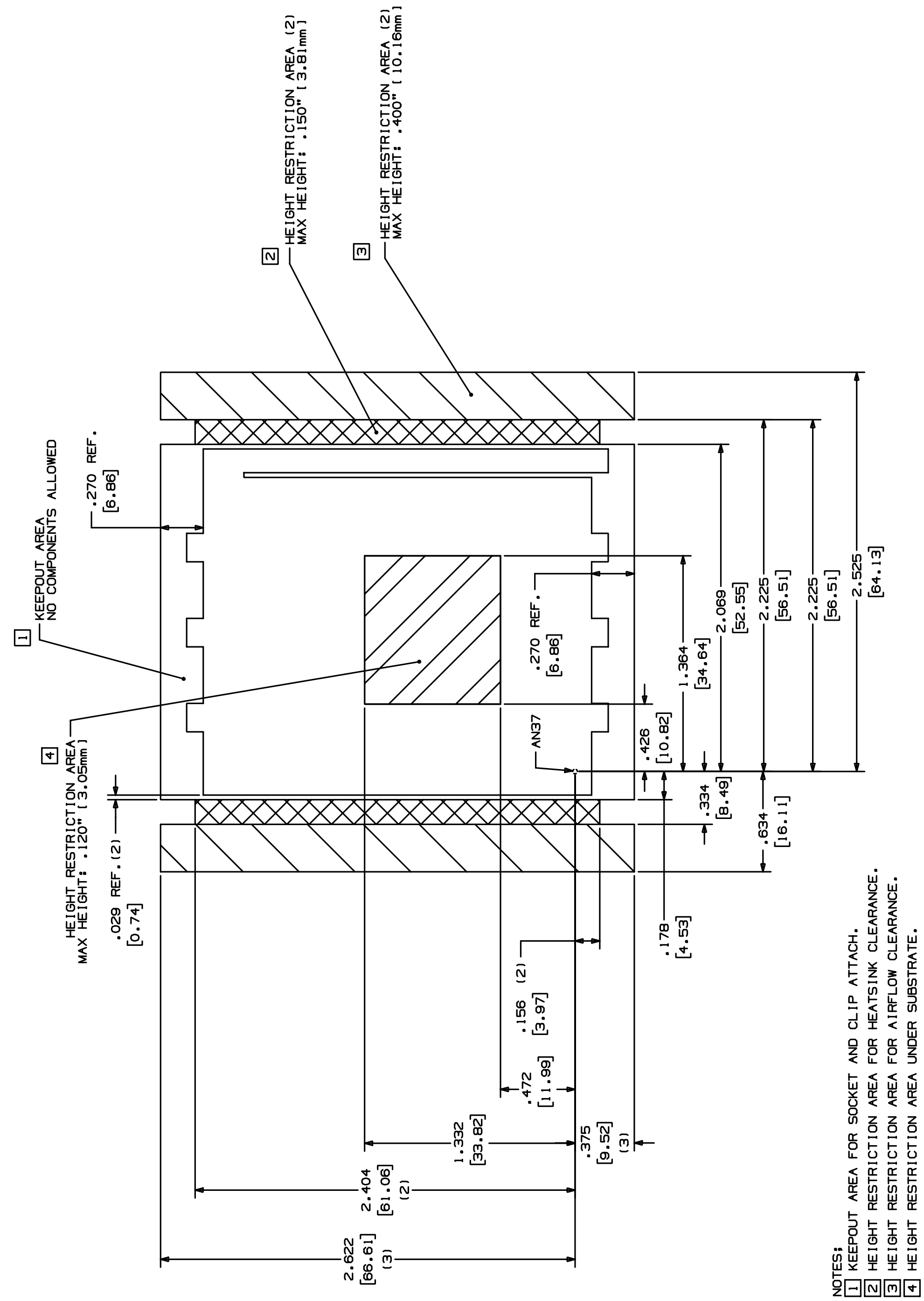


Figure 6. Motherboard Keepout Area for a Socket A AMD Duron™ Processor Heatsink

Thermocouple Installation for Temperature Testing

To install a thermocouple to measure the operating temperature of the heatsink, perform the following procedure:

1. Mark a location on the base of the heatsink as shown in Figure 7. Determine the position of the thermocouple hole using the following measurements:
   - a = 24.765 mm
   - b = caliper measurement
   - If the heatsink extends over the PGA processor (as it is diagrammed), then x = a + b
   - If the heatsink does not extend over the PGA processor, then x = a – b
   - y = 2 mm

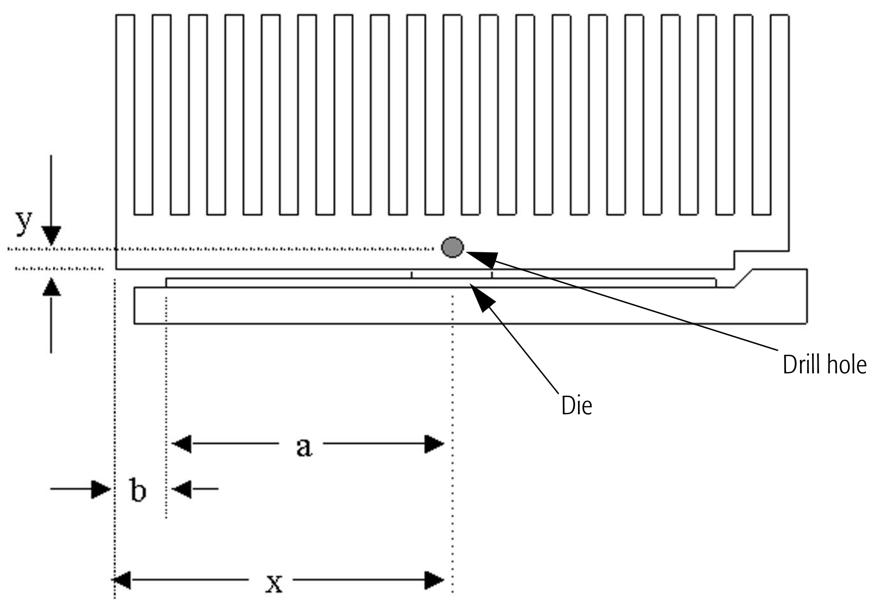


Figure 7. Measuring Thermocouple Position

2. Drill a hole at the marked location using a #53 drill bit (1.5113 mm or 0.0595 inches). If the heatsink is symmetric in relation to the processor package, drill to a depth of half the width of the heatsink. If it is not symmetrical to the processor, drill to a depth that is directly over the center of the die, as shown in Figure 8.

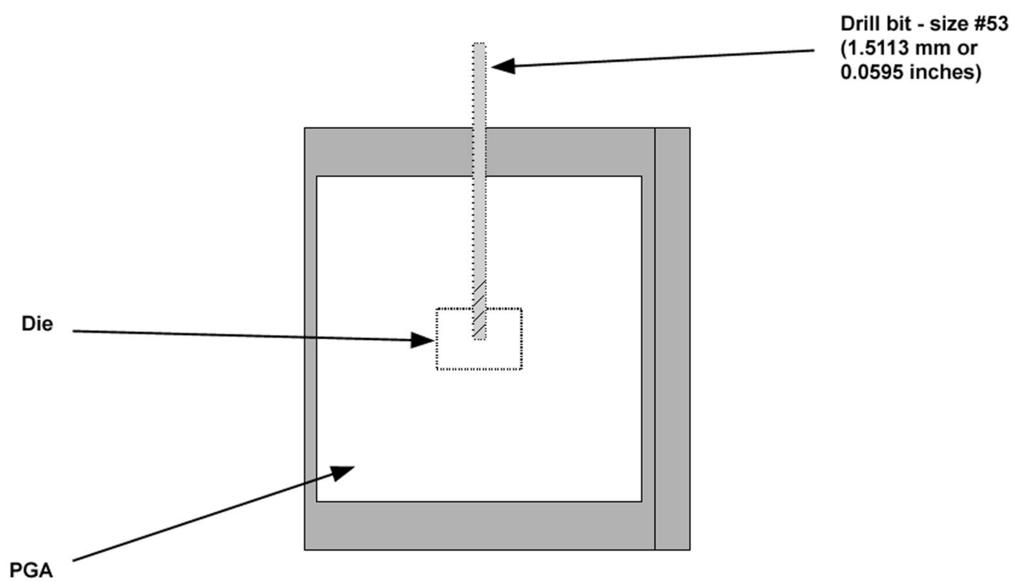


Figure 8. Bottom View of Heatsink and Drill Depth

3. Inject thermal grease into the newly drilled hole with a syringe as shown in Figure 9. Use Dow Corning 340 white thermal grease or it's equivalent.

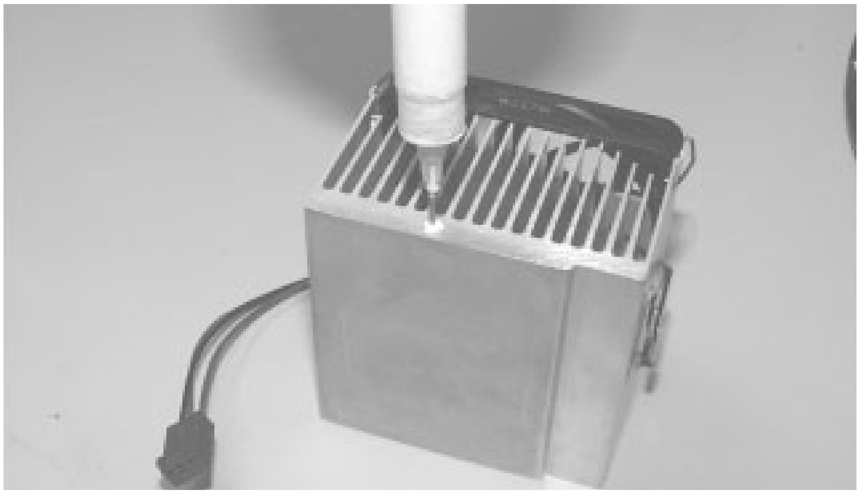


Figure 9. Injecting Thermal Grease into Drilled Hole

4. Gently insert the thermocouple into the hole until it bottoms out, and tape it down with Kapton tape, making sure not to kink the thermocouple. Figure 10 shows an installed thermocouple.

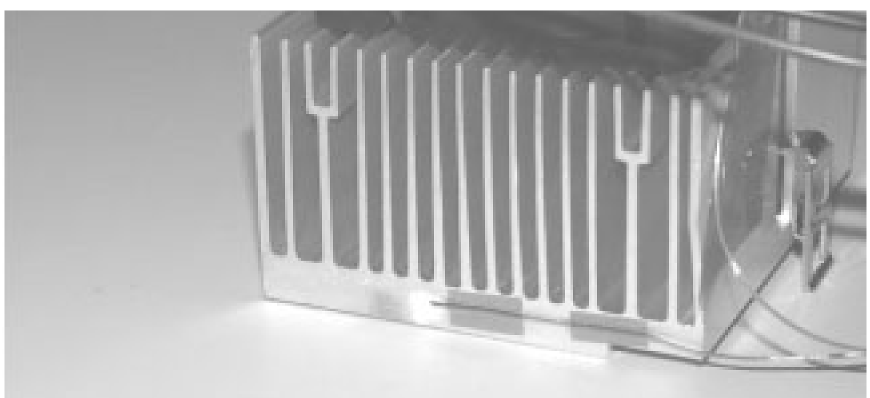


Figure 10. Installed Thermocouple

Chassis Cooling Guidelines

As high-performing systems continue to evolve, the power consumption of system components such as the processor, hard disk drives, and video cards continues to increase. The associated rise in power consumption can cause the system operating temperature specifications to be exceeded. The correct operating temperature of each system device can be controlled by providing proper airflow through the system case.

Chassis Airflow

System cooling is dependent on several essential and related factors. Figure 11 shows a typical mid-tower chassis with the internal physical characteristics and recommended airflow.

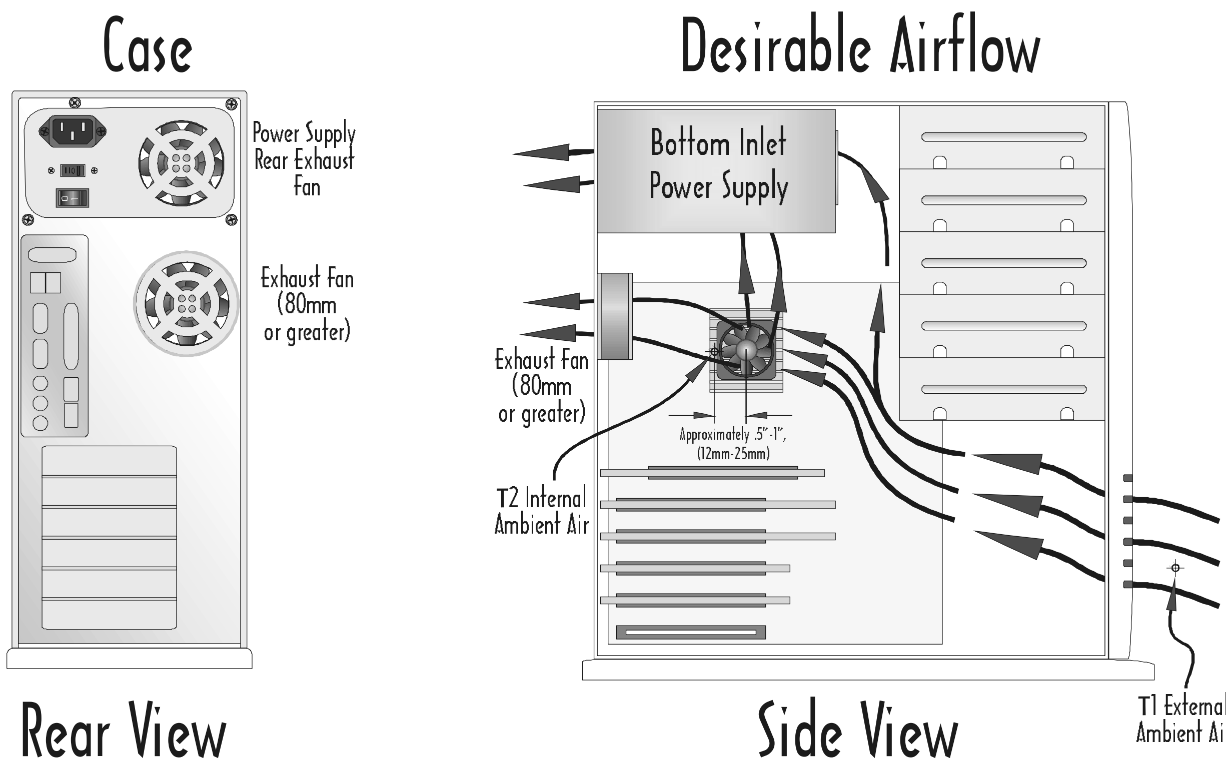


Figure 11. Airflow Through the Chassis

Using thermal couples (type K or T, 36 gauge) in the locations shown in Figure 11, temperatures T1 and T2 can be measured. T1 represents the external ambient air temperature. T2, which is located approximately 0.5 inch to 1.0 inch away from the processor fan (centered on the hub), represents the internal local ambient air temperature. **It is highly recommended that T2 not exceed 40°C**. The following equation shows how to derive the proper overall system operating temperature:

$\Delta T = T2 - T1$
$\Delta T \leq 7°C$ to ensure proper cooling

Power Supply as Part of the Cooling Solution

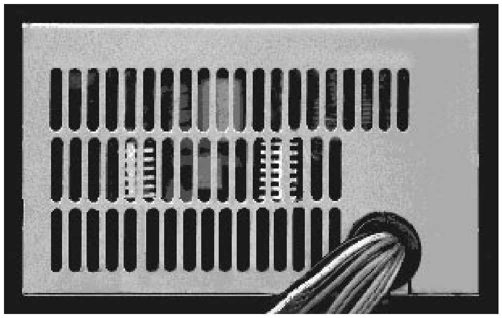
For full-tower or mid-tower cases, it is important for system designers to be aware of the characteristics of the power supply used. Designers should only use a power supply intended for use with the AMD Athlon or AMD Duron processors. Consult with your power supply vendor to verify suitability.

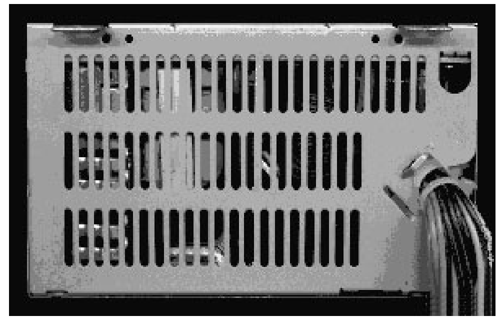
For best results, use a power supply with venting in the processor region, which means that the primary air intake is on the bottom of the power supply, usually with a secondary intake at the front of the power supply. For the purposes of this chapter, a power supply with bottom air intake is referred to as an *ATX-style* power supply. Some power supplies have *NLX-style* venting (the only air intake is at the front of the power supply). These power supplies do not pull significant amounts of air from the processor area.

Figure 12 on page 18 compares desirable power supply venting designs with designs that are less desirable. The front and rear designs for the desirable and less desirable versions are very similar (the differences depend on the brand). However, the bottoms of the more effective power supply designs incorporate an air intake. Power supply having bottom air intakes typically cool the processor more effectively. Bottom air intakes with fans normally provide even more effective cooling.

Desirable Version | **Less Desirable Version**

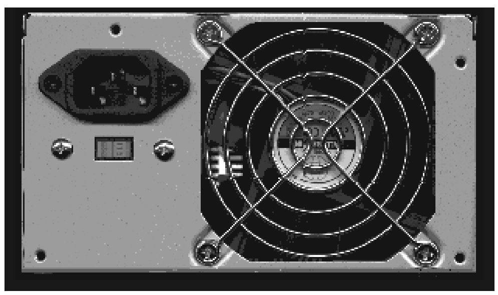
Front—

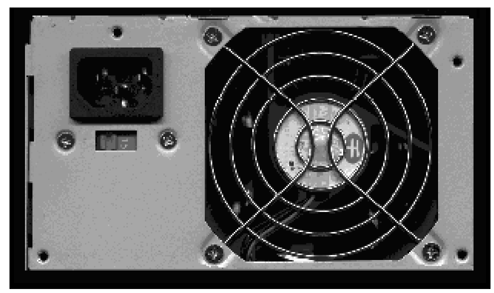




For the front air intake, the desirable and less desirable versions often are similar. Any differences depend upon the specific brand.

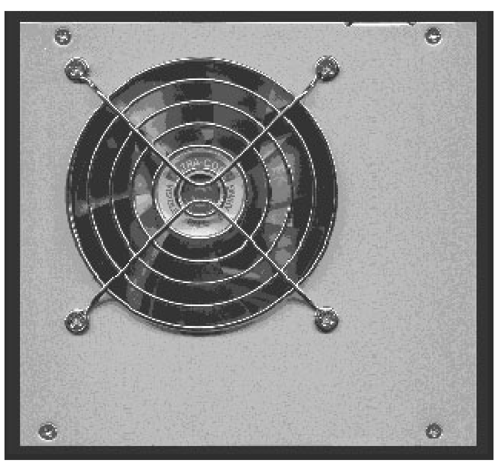
Rear—





For the rear air intake, the desirable and less desirable versions are essentially the same. Differences depend upon the specific brand.

Bottom—



On the bottom, the desirable version has an air intake. A bottom air intake typically cools the processor more effectively. If the bottom air intake has a fan, cooling is enhanced.

Figure 12. Power Supply Venting

Rules for Proper Cooling

The following basic rules for chassis cooling can provide adequate airflow and system temperatures:

- Use the proper heatsink for the processor speed used in the system. Make sure that the heatsink has appropriate sized fan(s). For the AMD-recommended choices, just go to www.amd.com/systemconfig and see the *AMD Athlon™ Processor Thermal Solutions* pages or the *AMD Duron™ Processor Recommended Cooling Solutions* pages. (Go to the processor configuration sections and then choice the appropriate pages.)
- Use only the AMD-recommended thermal interface materials listed in Table 7 on page 6. Typically, AMD-recommended heatsinks include a validated thermal compound. If you are replacing the heatsink's packaged compound, use only AMD-recommended thermal materials.
- Use an auxiliary exhaust rear chassis fan. The suggested size is 80 millimeters or larger. The fan intake should be near the location of the processor.
- For best results, use an ATX power supply with air intake venting in the processor region, which means that the primary air intake is on the bottom of the power supply, not at the front of the power supply. Supplies with *NLX-style* venting (the primary air intake is at the front of the power supply) do not pull air from the processor area.
- Make sure all the internal wires and cables are routed carefully so airflow through the case is not blocked or hindered. Using tie-wraps to contain loose items can help.
- Many cards, such as AGP cards, generate heat. Either leave the slot next to these cards open, or use a shorter card in these slots to allow airflow around heat producing cards (typically those cards with many electrical components).
- High-speed hard drives, especially 10,000+ RPM SCSI hard drives, produce a great deal of heat. You can mount these drives in 5.25 inch frames and install them in the larger drive bays. This mounting allows greater airflow around the drives for better cooling.
- A front cooling fan is not essential. In some extreme situations, testing has actually shown that these fans can recirculate hot air rather than introducing cool air.
- Maintain a $\Delta T \leq 7^{\circ}C$.

Conclusion

Thermal, mechanical, and chassis cooling solutions that meet the criteria described in the previous pages have been successful for applications incorporating AMD processors. AMD encourages vendors to innovate and propose other designs. If different heatsink production technologies, whether extrusion, folded fin, bonded fin, or cold forged, produce similar or better results than the solutions suggested in this guide, then designers are encouraged to incorporate them into new thermal solution designs. Any design, however, must meet the overall goal of dissipating the heat produced by the processor at a given ambient temperature.